REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
01-02-2010

2. REPORT TYPE
Final

3. DATES COVERED *(From - To)*
Feb 2007-Nov 2009

4. TITLE AND SUBTITLE
Foundations of Automatic Target Recognition

5a. CONTRACT NUMBER
FA9550-07-1-0295

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Karl, William C.

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Boston University
8 St. Mary’s Street
Boston, MA 02215

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Dr. Jon Sjogren
Air Force Office of Scientific Research
875 North Randolph Street
Suite 325, Rm 3112
Arlington, VA 22203

10. SPONSOR/MONITOR’S ACRONYM(S)

11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Public Release

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The research funded under this grant focused on several key challenges arising in automatic target recognition (ATR) systems. The robust estimation of geometric features is a critical aspect of ATR systems and thus methods for robust boundary extraction and feature enhancement were developed based on both statistical modeling and compressed sensing. Another set of challenges was related to novel, non-conventional sensing geometries arising in modern layered-sensing systems. Traditional sensing has focused on single sensors and single aspects, e.g. conventional mono-static, narrow aspect SAR. But as new sensing paradigms are considered, new methods for image estimation and processing are needed. In response, novel, robust methods for wide-angle image formation and multi-static multi-sensor data fusion were developed, based on powerful sparsity constraints. In addition, recent methods from compressed sensing were applied to SAR imaging problems of interest to the Air Force to reduce sampling requirements and improve robustness. Finally, imaging of scenes with moving targets has become a problem of great interest to AFRL. In response new methods for the formation and treatment of scenes with motion were developed based on over complete dictionaries.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Dr. Jon Sjogren
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(include area code)*

Summary

The research funded under this grant focused on several key challenges arising in automatic target recognition (ATR) systems. The robust estimation of geometric features is a critical aspect of ATR systems and thus methods for robust boundary extraction and feature enhancement were developed based on both statistical modeling and compressed sensing. Another set of challenges was related to novel, non-conventional sensing geometries arising in modern layered-sensing systems. Traditional sensing has focused on single sensors and single aspects, e.g. conventional mono-static, narrow aspect SAR. But as new sensing paradigms are considered, new methods for image estimation and processing are needed. In response, novel, robust methods for wide-angle image formation and multi-static multi-sensor data fusion were developed, based on powerful sparsity constraints. In addition, recent methods from compressed sensing were applied to SAR imaging problems of interest to the Air Force to reduce sampling requirements and improve robustness. Finally, imaging of scenes with moving targets has become a problem of great interest to AFRL. In response new methods for the formation and treatment of scenes with motion were developed based on over complete dictionaries. These efforts are elaborated below.

Boundary extraction and feature enhancement

A new method was developed for joint object boundary extraction and feature enhancement and applied to laser-radar imaging problems. This method uses a joint object boundary and intensity model, where curve evolution approaches are used to explicitly capture the object boundary. In contrast to traditional, two-step sub-optimal “smooth and segment” approaches, the new approach optimally uses the data, and thus provides superior performance as data quality and quantity are reduced. While curve evolution methods have gained popularity in academic circles, their impact in practice has been limited due to their significant computational demands. In response we developed new real time algorithms for level-set based curve evolution and demonstrated that video-rate curve evolution processing of images was possible.

Non-conventional, layered sensing

Traditional sensing has been accomplished by independent, single sensors from single aspects. Recently there has been great interest in multi-aspect, multi-sensor, layered sensing, involving non-traditional sensing geometries, multi-static, multi-sensor collaboration. Examples include the wide-angle, circular SAR of the “GOTCHA” data set, multi-static radar, and recent work in waveform diversity. These new sensing paradigms require new processing approaches, as conventional narrow aspect, single sensor algorithms perform poorly in these cases. In response new methods were developed to address a subset of these problems. Focusing on radar imaging, traditional isotropic scattering models were extended to account for the possibility of aspect dependent behavior that becomes an issue e.g. in wide-aspect SAR. These aspect-dependent models were then used as the basis of image formation methods which estimated the aspect dependent scattering behavior of scenes. These new approaches provide a much richer set of information concerning objects in a scene than traditional methods, with the possibility of improving discrimination.

Further, new multi-input multi-output (MIMO) multi-static radar sensing configurations were considered. Using the multi-static radar models of Wicks, Cheney, et al, new image formation methods were developed allowing the formation of high-quality imagery for these scenarios. These approaches demonstrated higher resolution, better localization, and improved anomaly suppression over existing methods based on filtered back project-type algorithms. In addition, new tools from compressed sensing were applied to reducing the amount of sensing required in multi-static acquisitions and to optimize the distribution of sensing probes, laying the foundations for a compressed sensing theory for multi-static SAR. This appeared to be the first such work in this area.

Lastly, imaging of dynamic scenes were examined. Traditionally in radar imaging, two different modes of sensing have been employed to cope with moving and static targets. Ground MTI radar has been used to track moving targets, but cannot image them. Once the targets stop, they are then imaged with SAR to provide classification, type etc. Recently there has been interest in initiating and maintaining tracking of specific vehicles, leading to a desire for moving target SAR imaging. In response, new methods for imaging of moving targets from SAR-type sensed data were developed. These techniques were based on the use of a overcomplete dictionaries of target location and motion and exploited recently developments in compressed sensing and sparsity-based reconstruction.

Publications

1) H. Feng, D. A. Castanon, W. C. Karl, ``Unified Anomaly Suppression and Boundary Extraction in Laser Radar Range Imagery based on a Joint Curve-Evolution and Expectation-Maximization Algorithm,'' IEEE Trans. Image Processing, Vol 17, No. 5, pg 757-766, May 2008.
2) Y. Shi and W. C. Karl, ``A Real-Time Algorithm For The Approximation Of Level-Set-Based Curve Evolution,'' IEEE Trans. on Image Processing, Vol. 17, No. 5, Pg 645-656, May, 2008.
3) Ivana Stojanovic, W. Clem Karl, Mujdat Cetin, ``Joint space aspect reconstruction of wide-angle SAR exploiting sparsity,'' Proceedings of SPIE: Algorithms for Synthetic Aperture Radar Imagery XV, Vol. 6970, March, 17-18, 2008.
4) Ivana Stojanovic, W. Clem Karl, "An overcomplete dictionary approach to imaging of moving targets with multistatic SAR," Compressive Sensing Workshop, Duke University, Feb 25-26, 2009.
5) Ivana Stojanovic, W. Clem Karl, Mujdat Cetin, "Compressed sensing of monostatic and multistatic SAR," Proceedings of SPIE: Algorithms for Synthetic Aperture Radar Imagery XVI, Vol. 7337, April, 14-16, 2009.
6) I. Stojanovic and W. C. Karl, ``Imaging of moving targets with multistatic SAR using an overcomplete dictionary,'' Journal of Selected Topics in Signal Processing, special issue on MIMO Radar, Vol. 4, No. 1, Pg. 164-176, February 2010.